



... for a brighter future

Inflation-era High Energy Physics and neutrino masses via CMB polarization measurements with the South Pole Telescope

John Carlstrom, Clarence Chang*, Aaron Datesman, Valentyn Novosad, John Pearson, Gensheng Wang, Volodymyr Yefremenko (Argonne)*

Critical component: Argonne TES Detector Development Project featuring HEP, MSD, and CNM.

COLLABORATORS:

South Pole Telescope collaboration including key people at: Kavli Institute for Cosmological Physics at the University of Chicago, U.C.Berkeley & LBL, U.Colorado, Case Western & McGill University



UChicago ►
Argonne LLC



A U.S. Department of Energy laboratory
managed by UChicago Argonne, LLC

**joint Argonne/U.Chicago*

*HEP provides enabling technology
for frontier research - excellent synergy.*

TECHNOLOGY

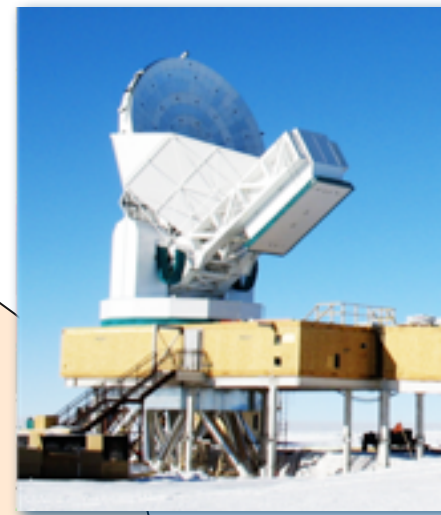
- Superconducting Transition-Edge Sensor (TES) Detectors
- Argonne TES Development Project
- Seeded by LDRD (ANL)

PLATFORM

- South Pole Telescope. Cutting edge instrument & strong collaboration
- PI: John Carlstrom

SPTpol

HEP Science

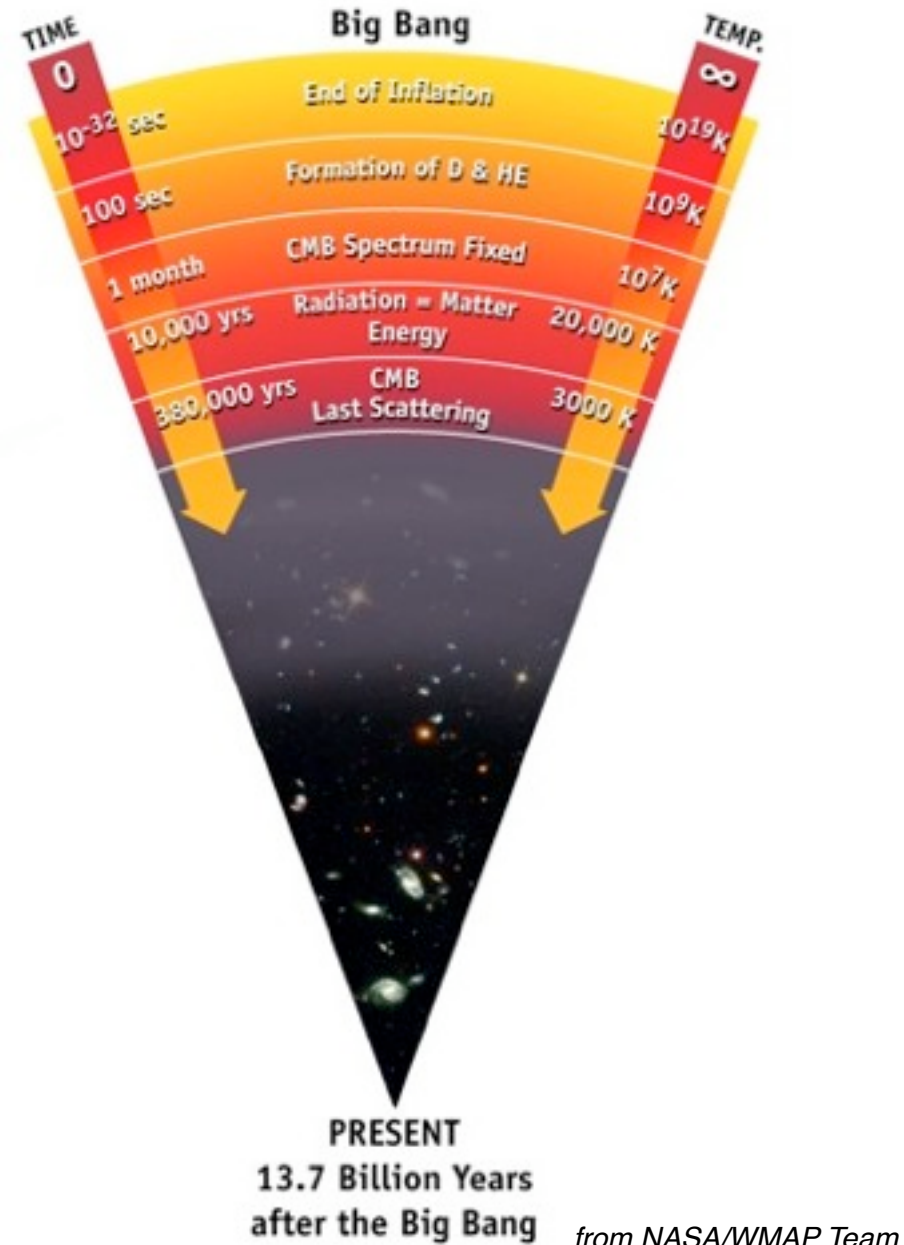


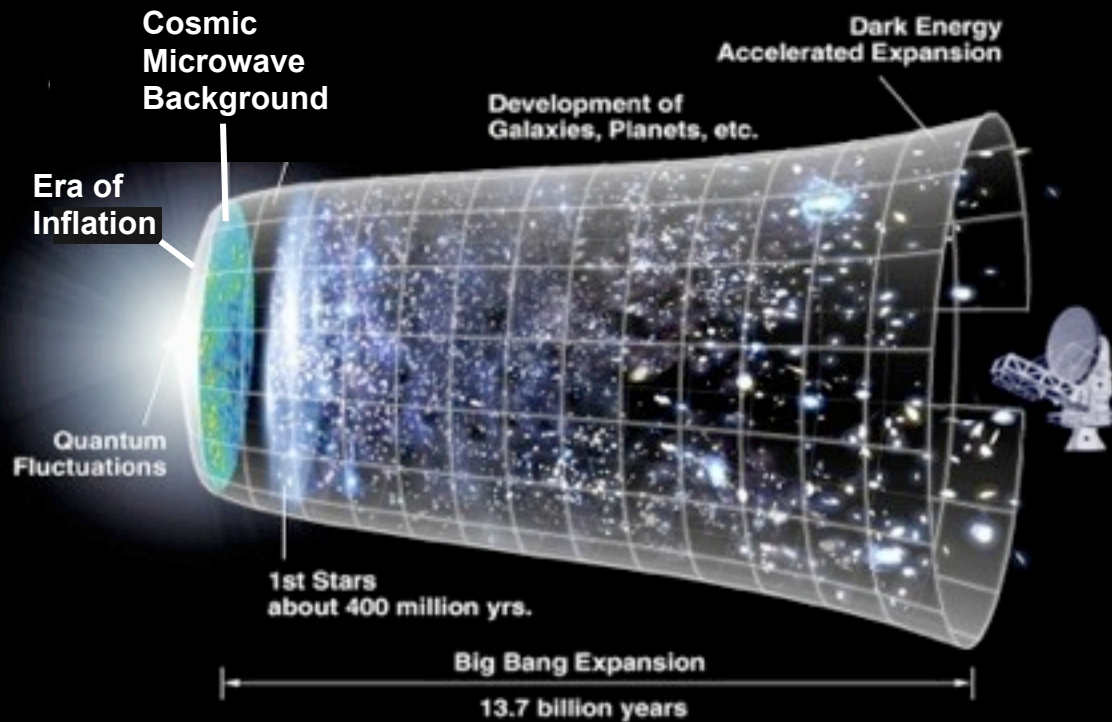
Probing the Cosmic Frontier

We now have a model that describes the evolution of our Universe from a hot and dense state.

The model has some unusual features - new physics - Dark Matter, Dark Energy, and starts with a period of Inflation.

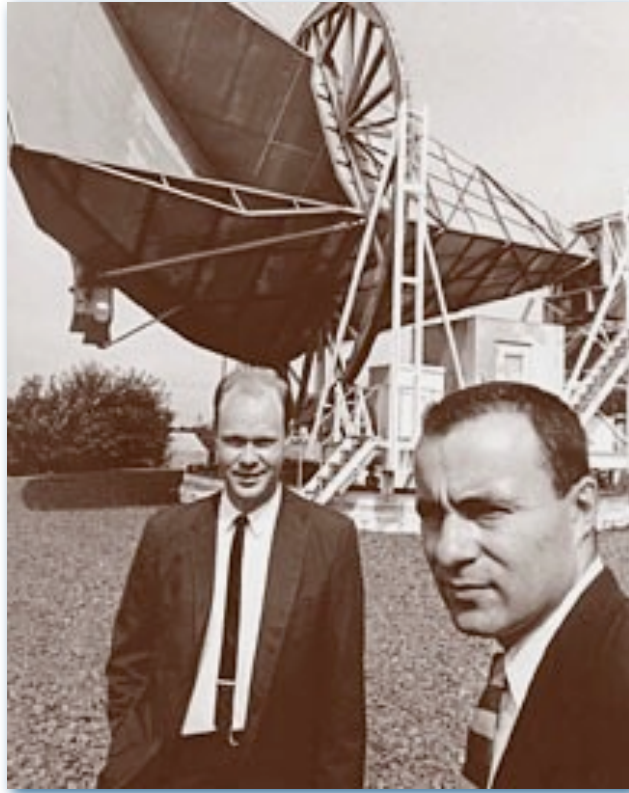
Most of the model has been learned from measurements of the cosmic microwave background (CMB).





Modified from NASA/WMAP Science Team [http://map.gsfc.nasa.gov/m_ig/060915/CMB_Timeline75.jpg]

Discovery of the Cosmic Microwave Background



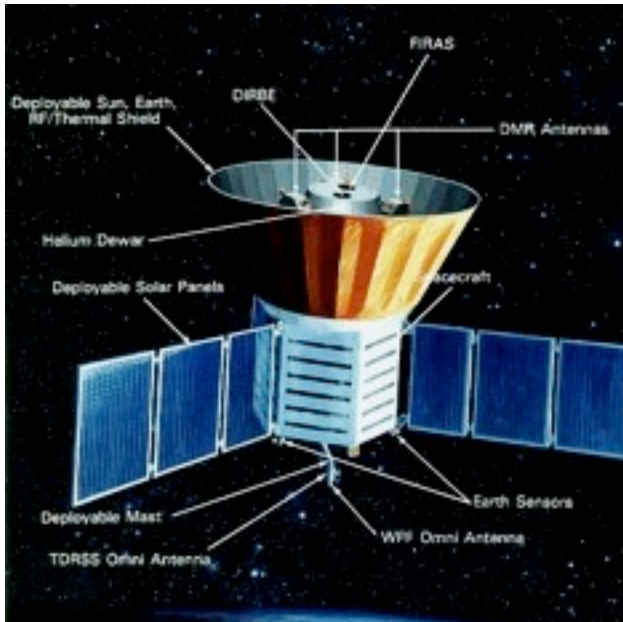
***“smoking gun”
evidence for the
Hot Big Bang***

Penzias & Wilson 1965

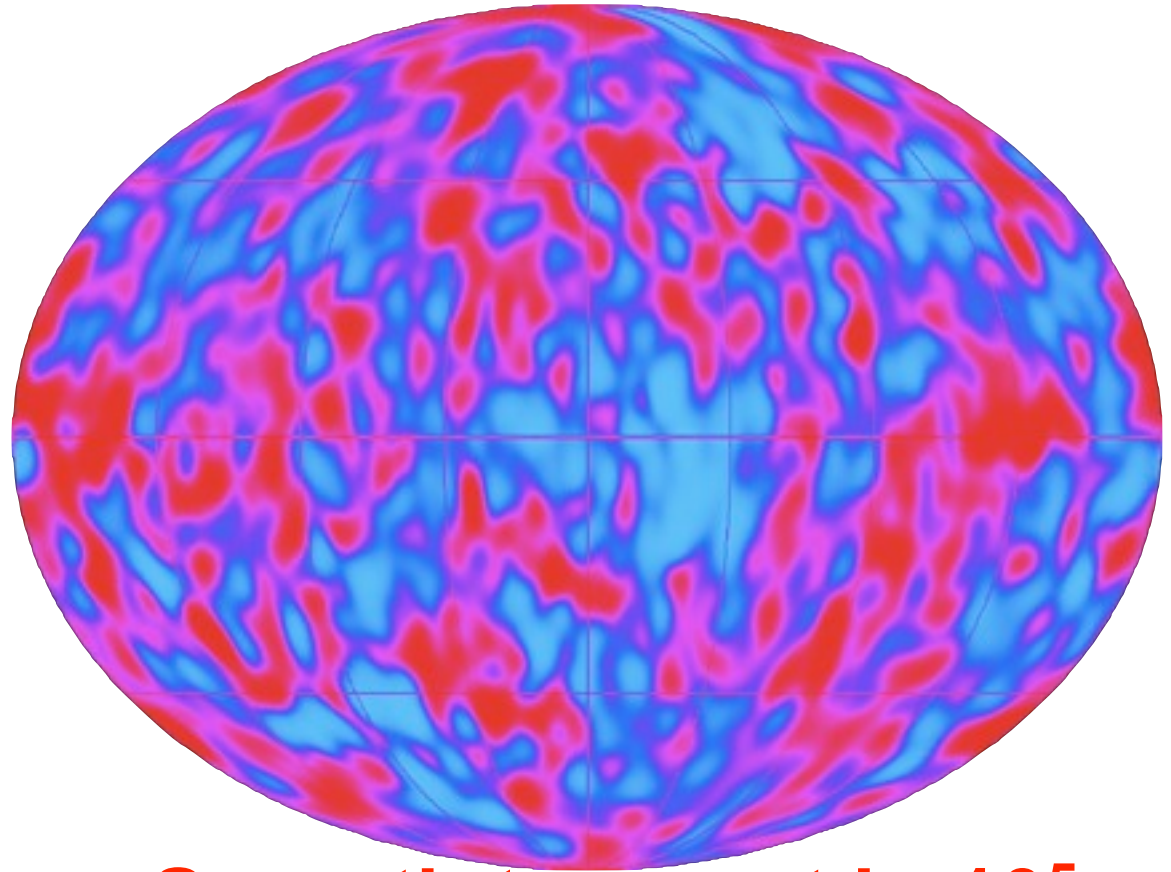
Received 1978 Nobel Prize

**Enormous
impact
on Cosmology**

Structure in background discovered in 1992



COBE Satellite



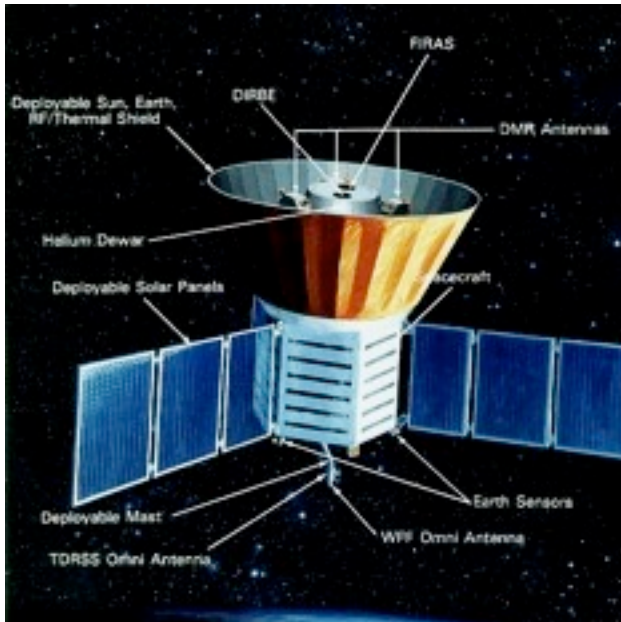
Smooth to a part in 10^5

*the smoothness problem -
led to Inflation theory*

Structure in background discovered in 1992

Superhorizon features

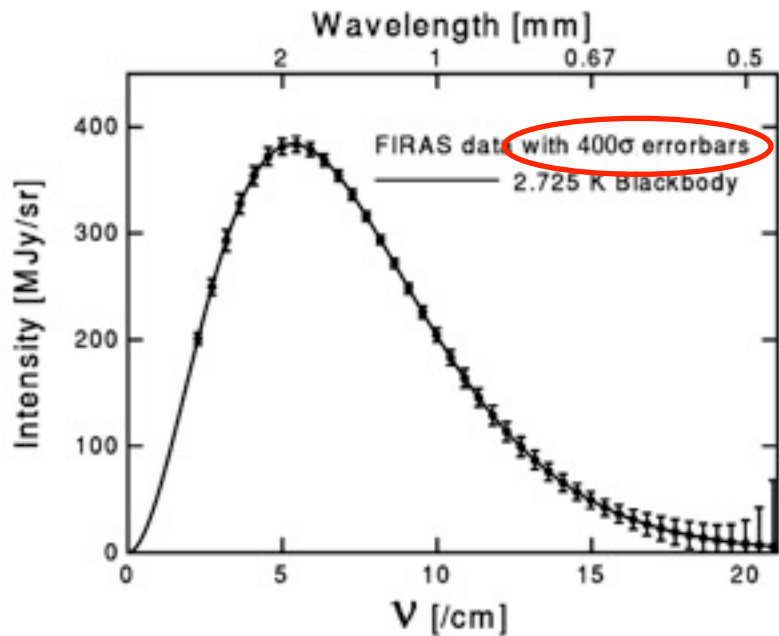
**Quantum fuzz inflated to the
largest structures in the universe**



COBE Satellite

Smooth to a part in 10^5

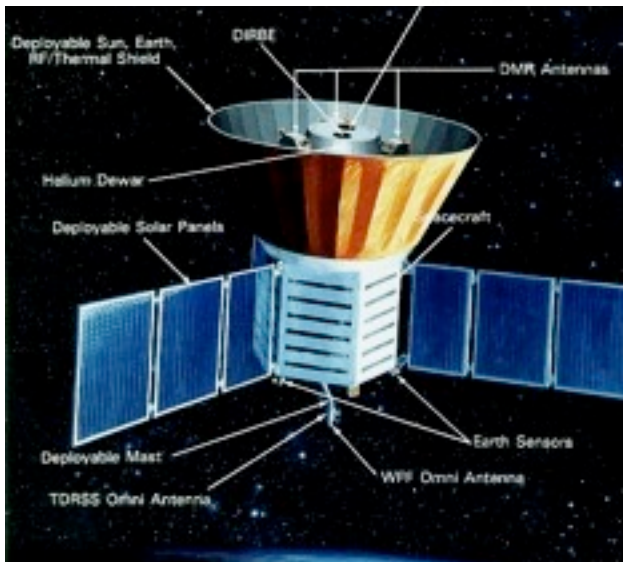
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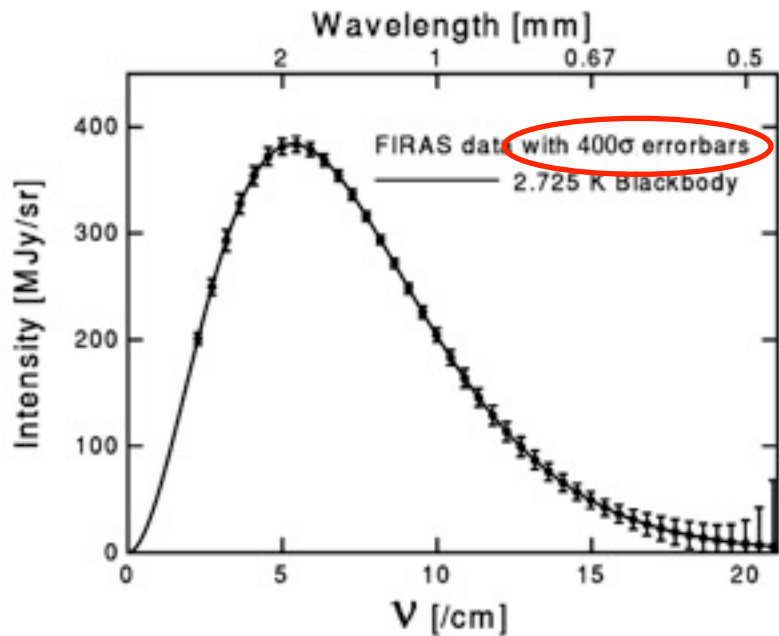


COBE Satellite



Smooth to a part in 10^5

*the smoothness problem -
led to Inflation theory*



und dis

COBE team leaders
John Mather & George Smoot
received 2006 Nobel Prize

Superhorizon features

*Quantum fuzz inflated to the
largest structures in the universe*



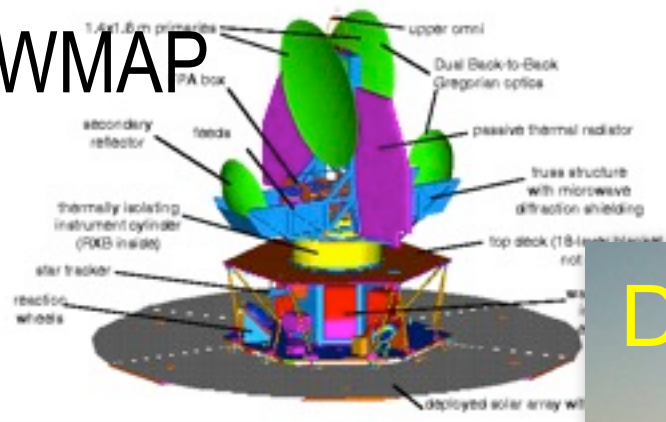
COBE Satellite



Smooth to a part in 10^5

*the smoothness problem -
led to Inflation theory*

WMAP



TOCO

Experiments

DASI



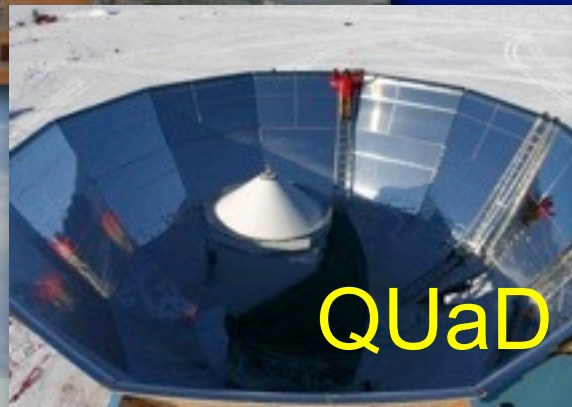
VSA



ACBAR



QUaD



Maxima



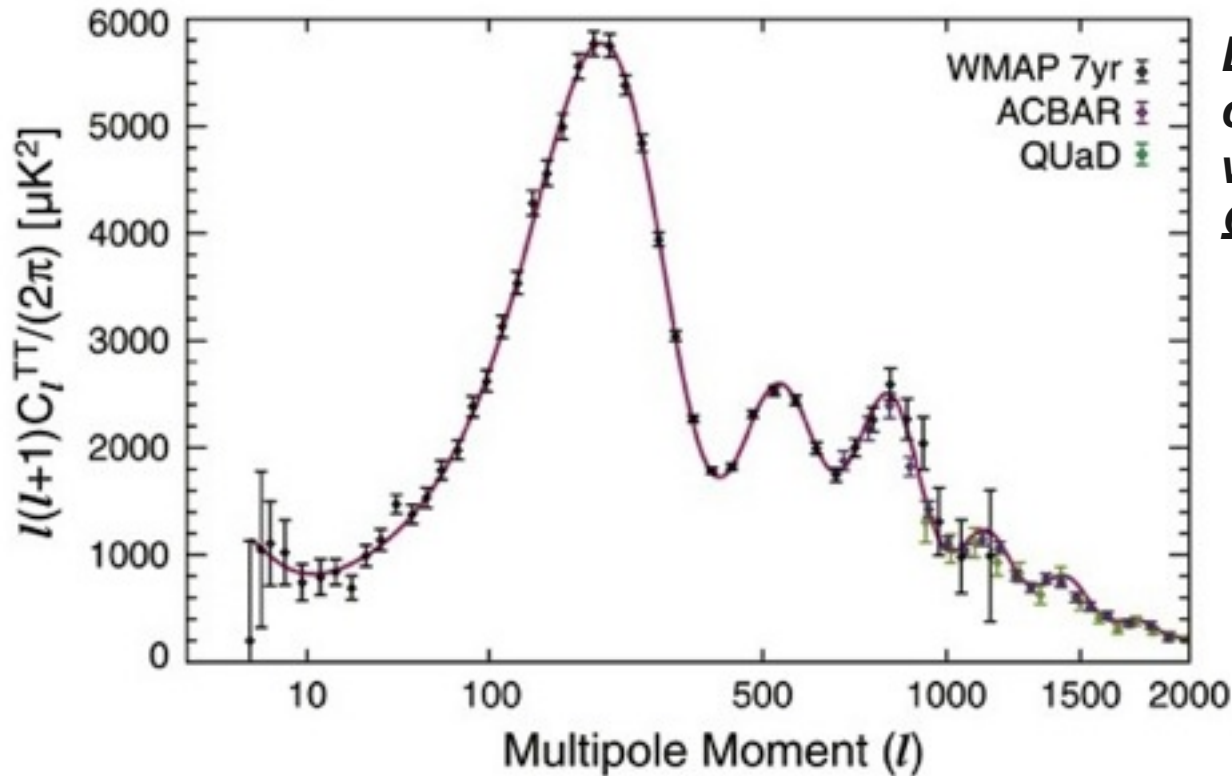
CBI



BOOMERanG



Incredible progress



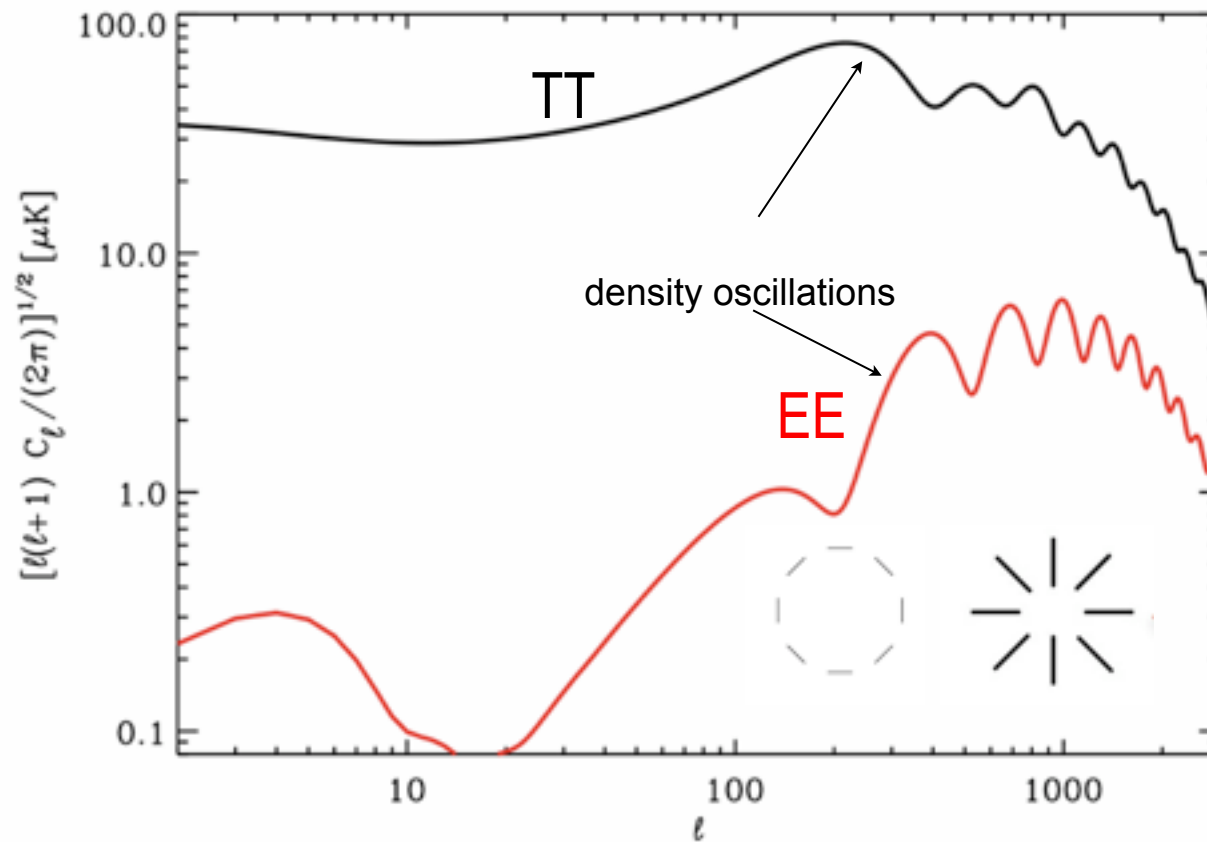
Line is fit to a flat Λ CDM cosmology model with just six parameters: $\Omega_b h^2$, $\Omega_m h^2$, A_s , τ , n_s , Ω_Λ

What's next? “B-mode” CMB polarization to probe Inflation.

The data from SPTpol will constrain the masses of the neutrinos and set (or limit) the energy scale of Inflation.

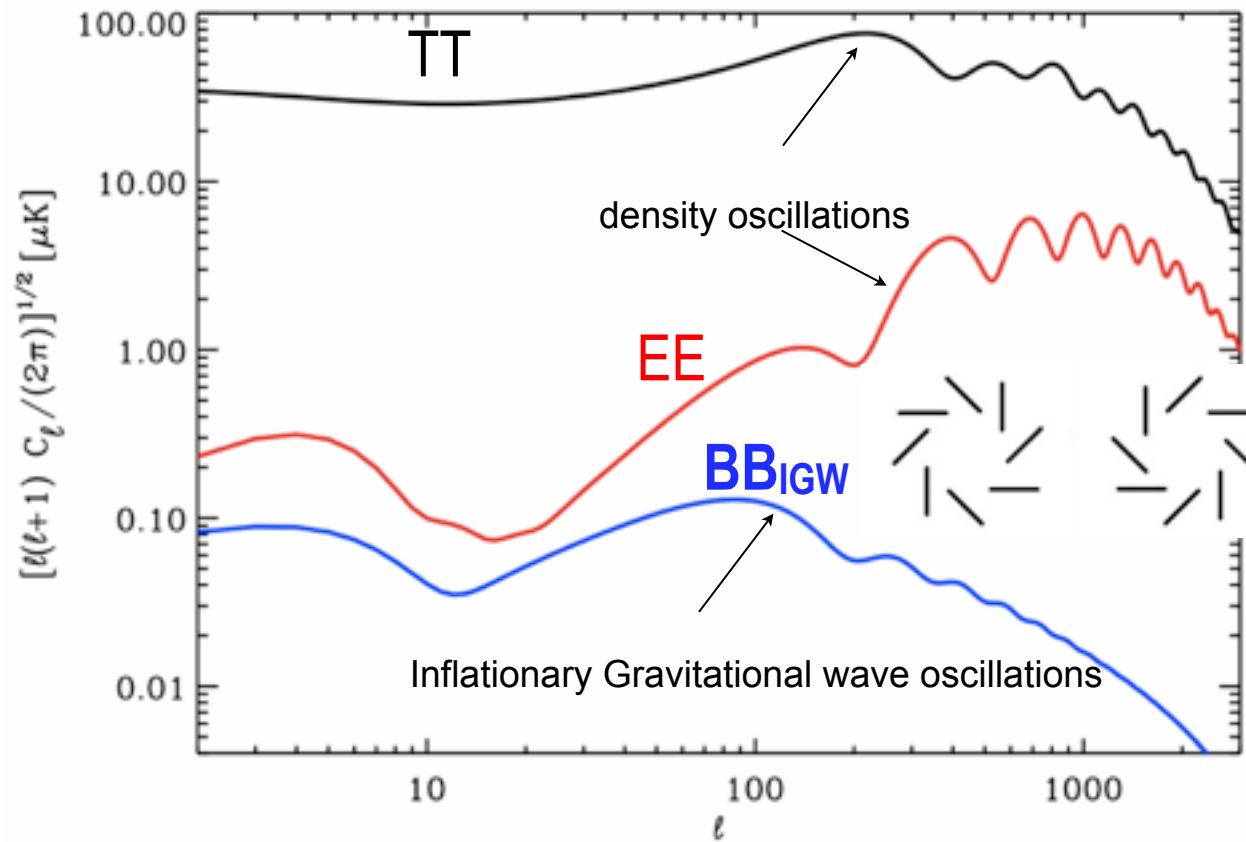
Komatsu et al., arXiv:1001.4538; Larson et al., arXiv:1001.4635

CMB angular power spectra

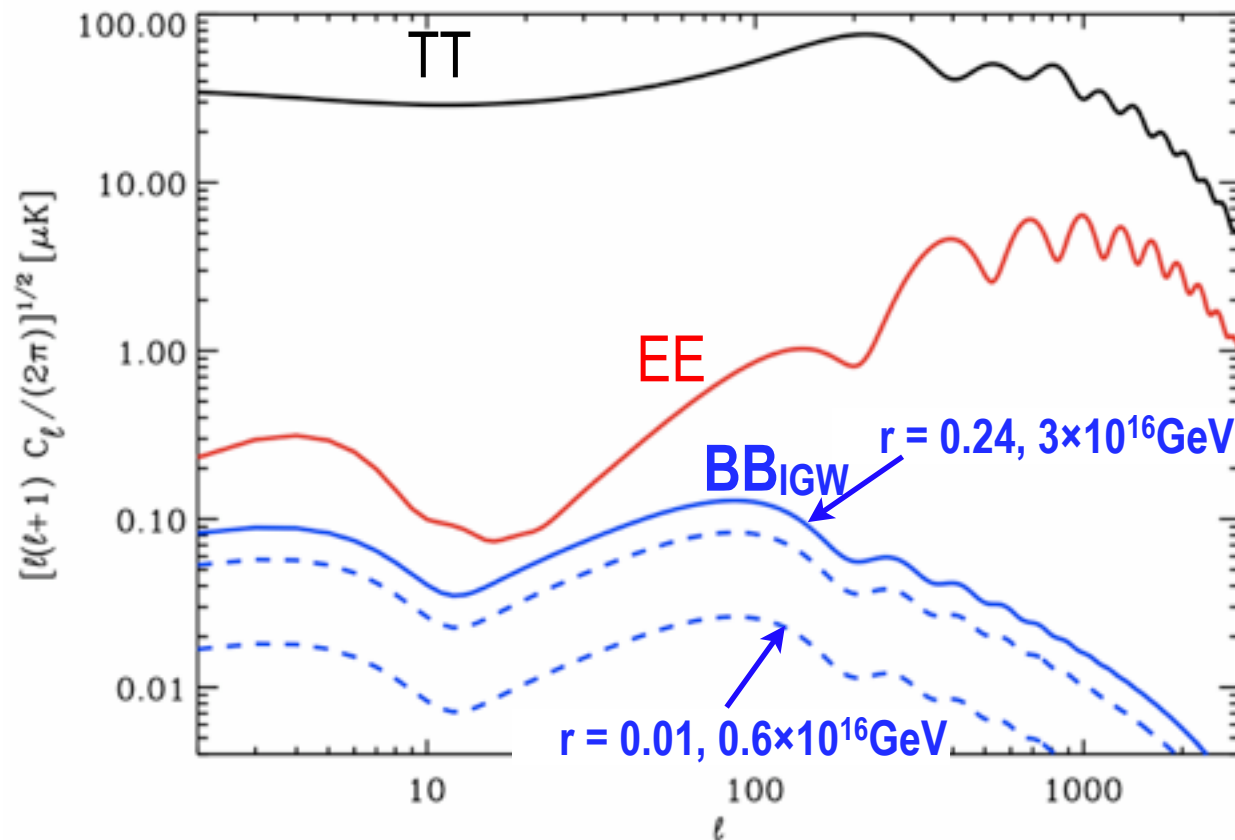


Spectra generated with WMAP7 parameters using CAMB, Lewis and Challinor

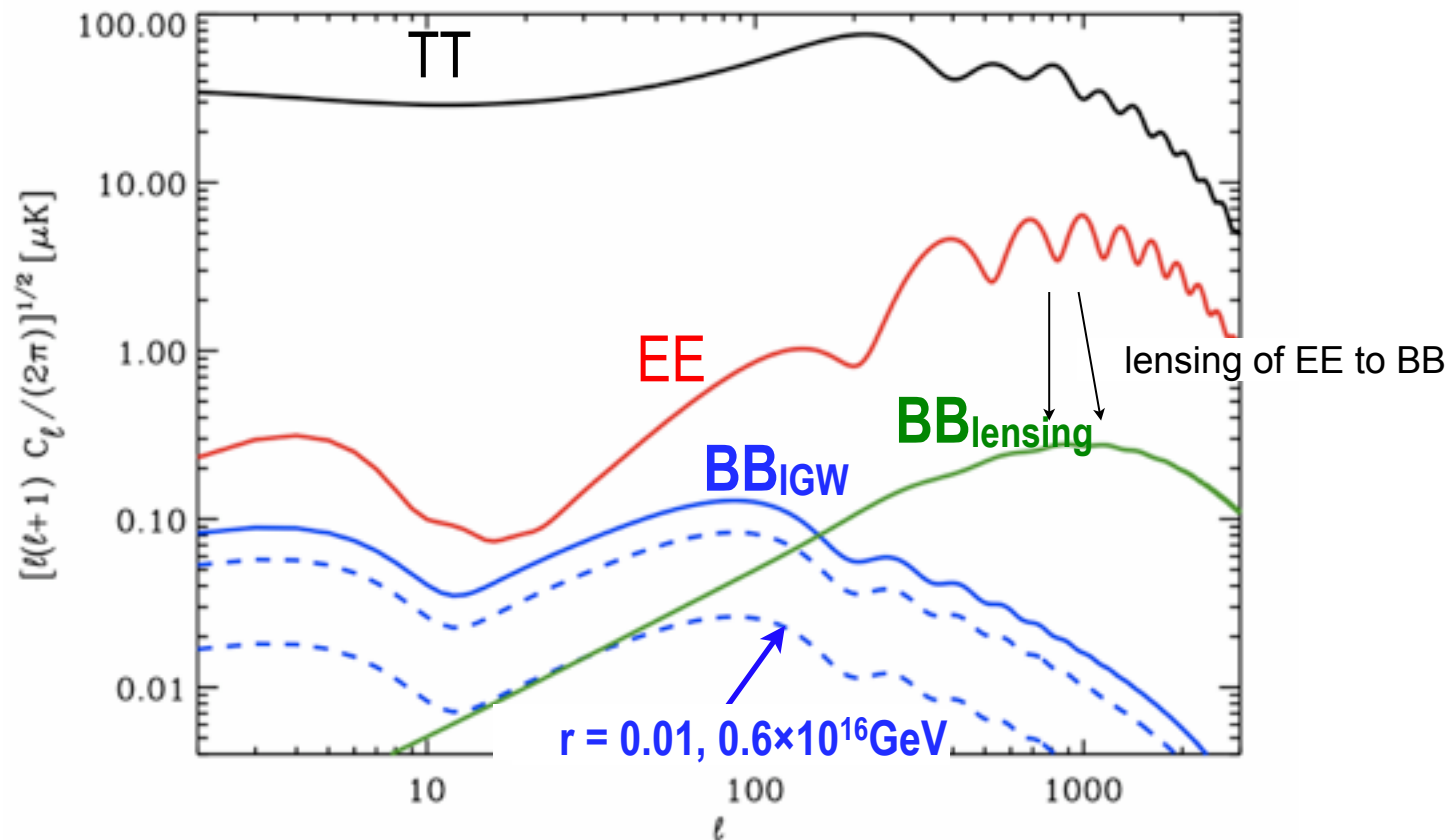
CMB angular power spectra



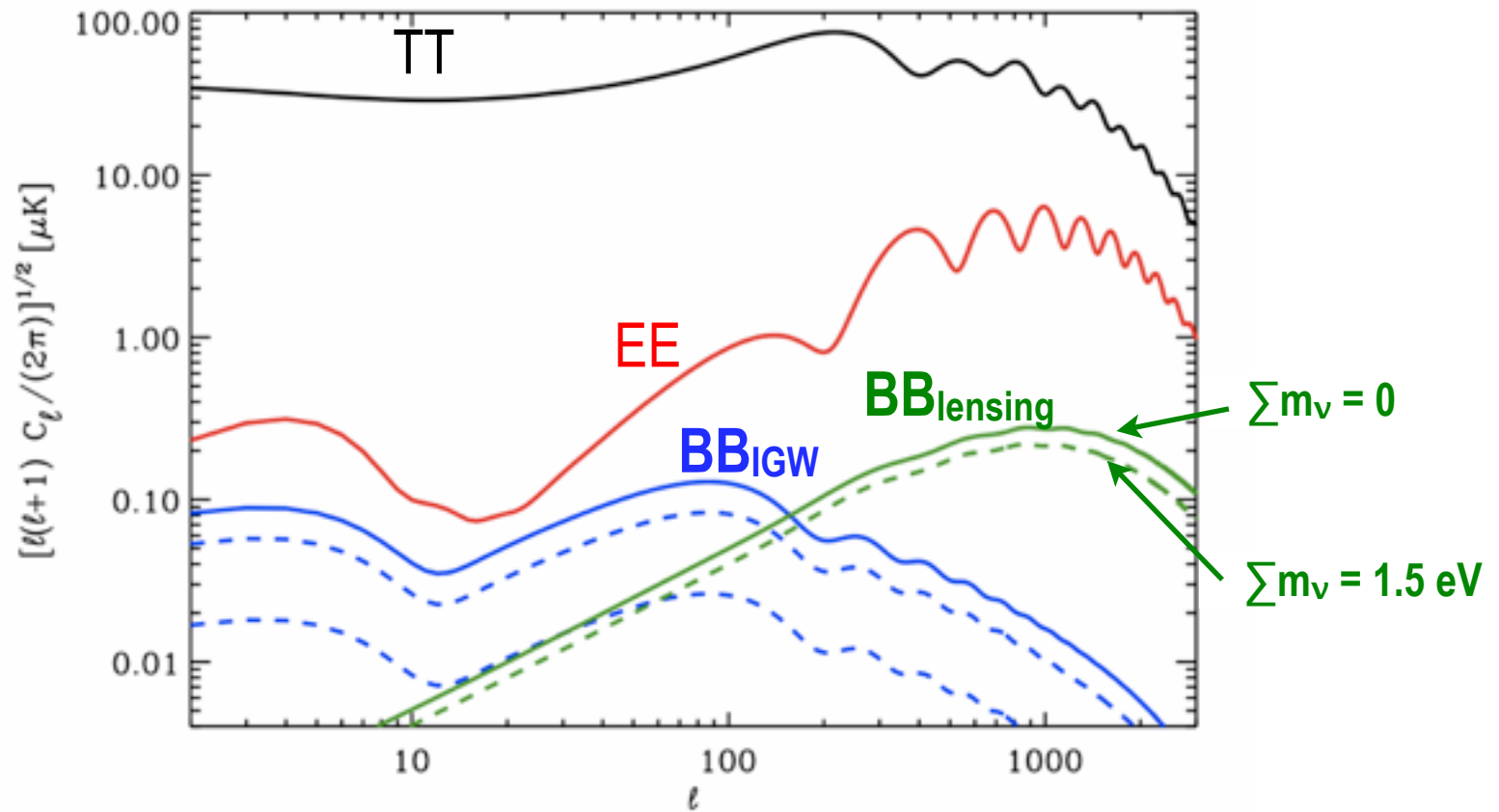
CMB angular power spectra



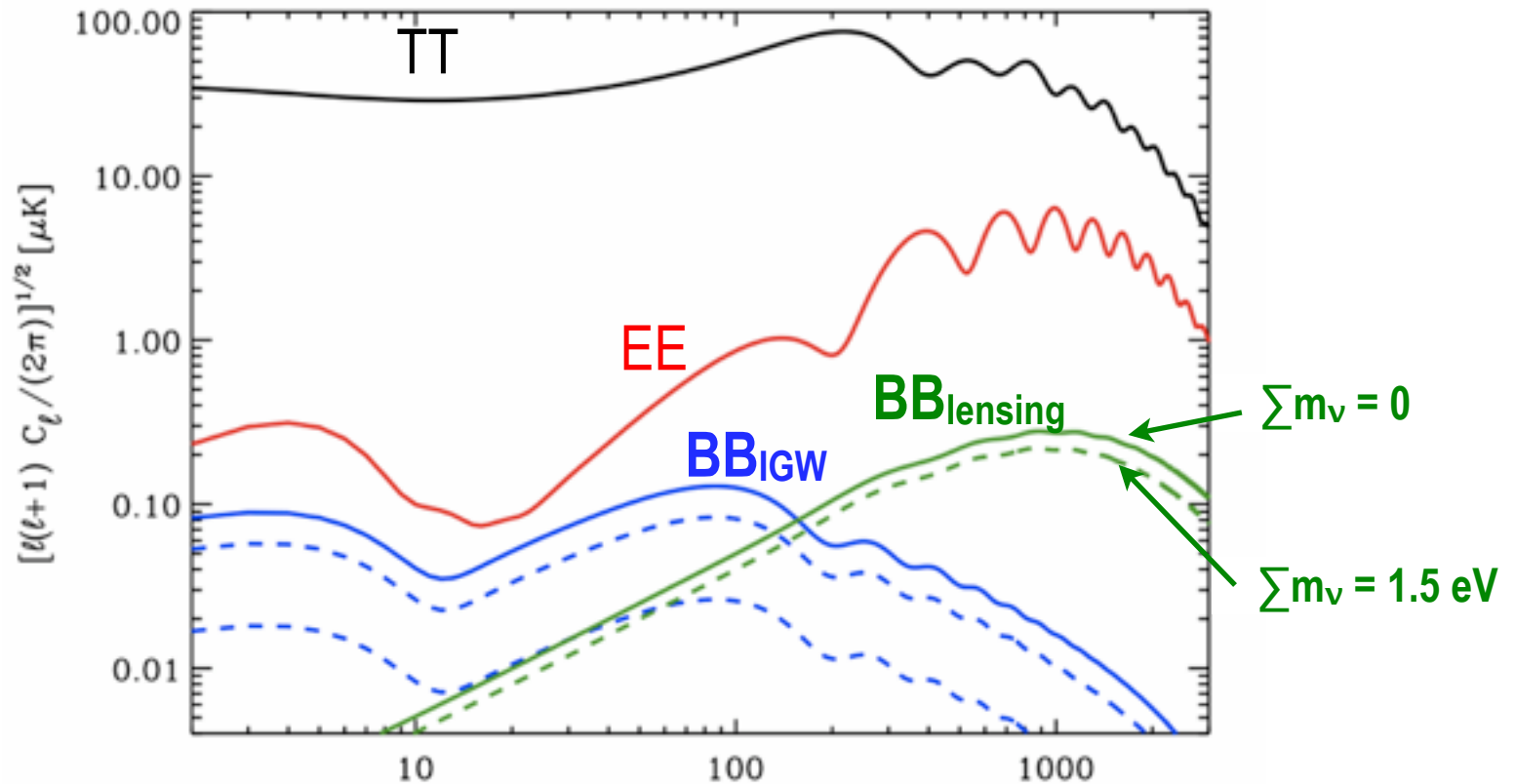
CMB angular power spectra



CMB angular power spectra



CMB angular power spectra

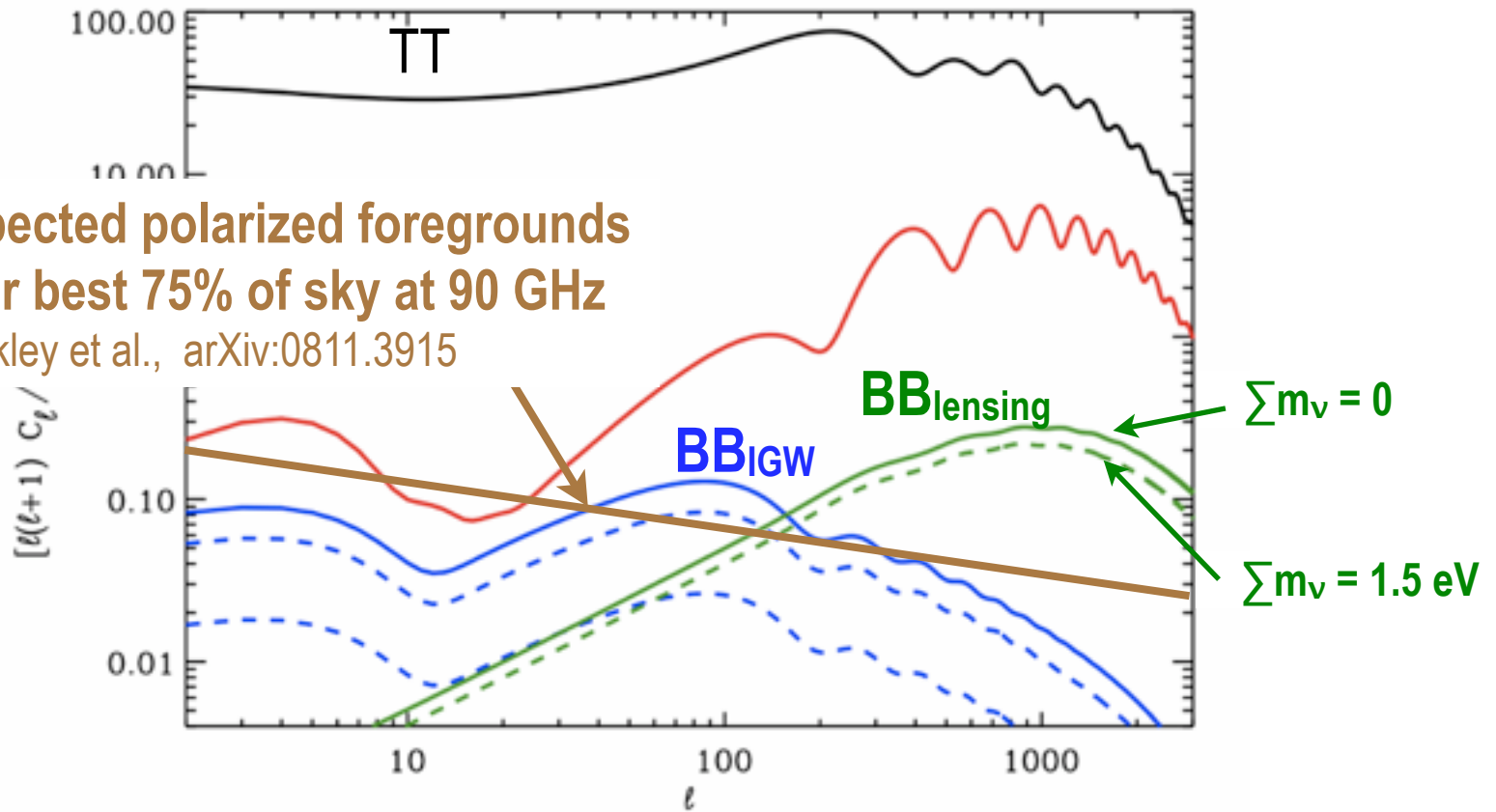


CMB measurements should be able to achieve $\sigma(\sum m_\nu) = 0.05 \text{ eV}$, comparable to Δm measured by neutrino oscillations.

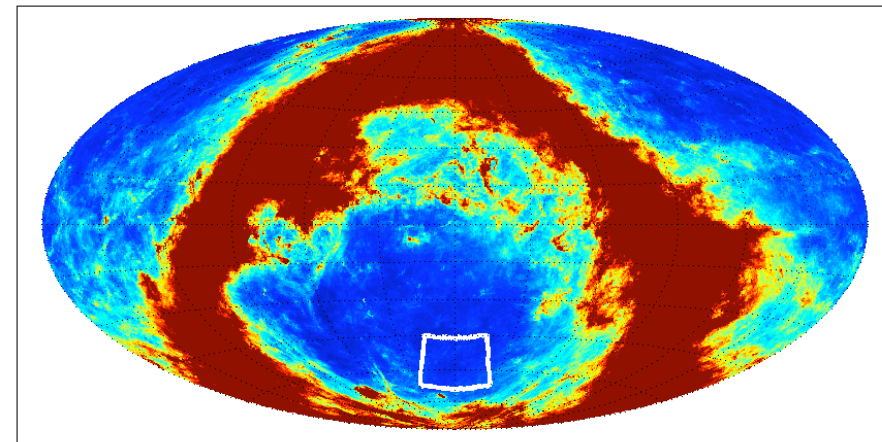
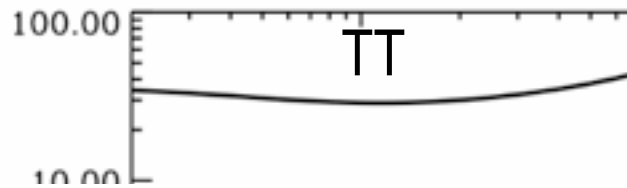
CMB angular power spectra

Expected polarized foregrounds
over best 75% of sky at 90 GHz

Dunkley et al., arXiv:0811.3915

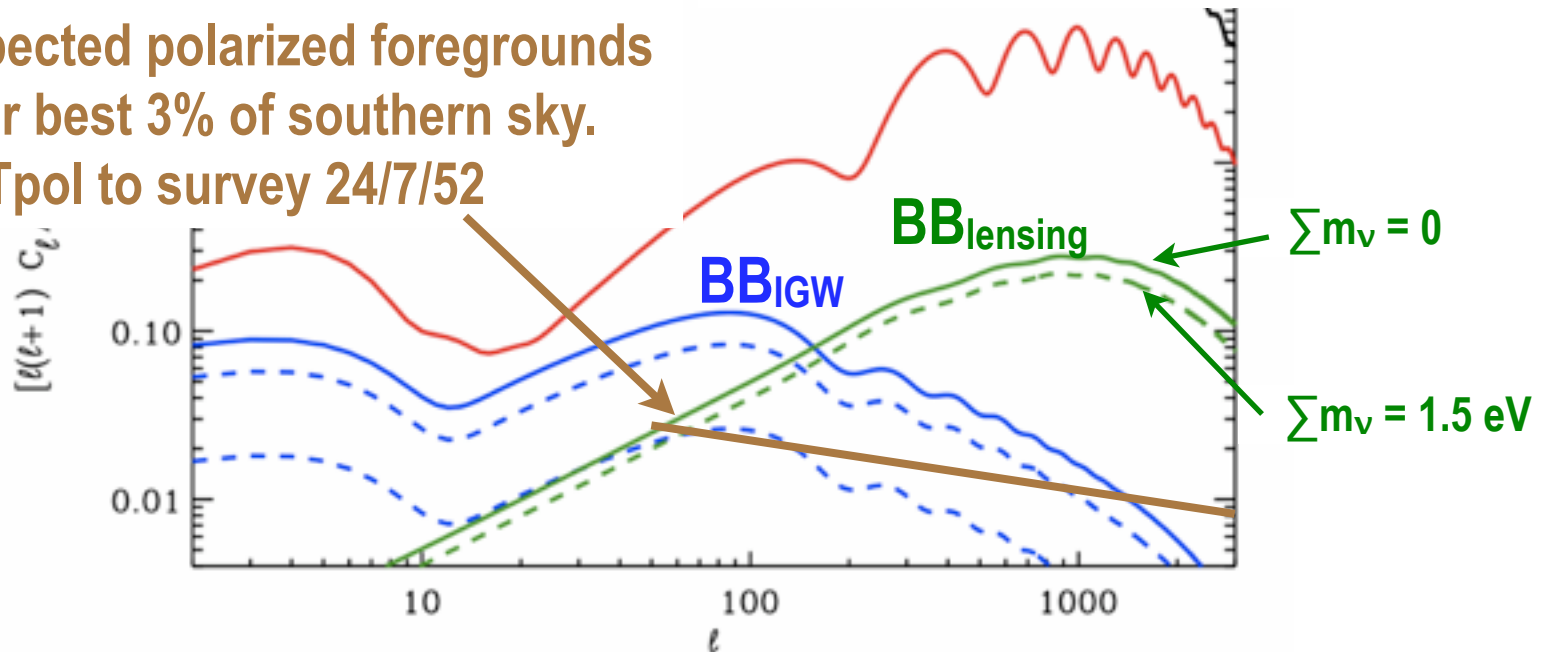


CMB angular power spectra

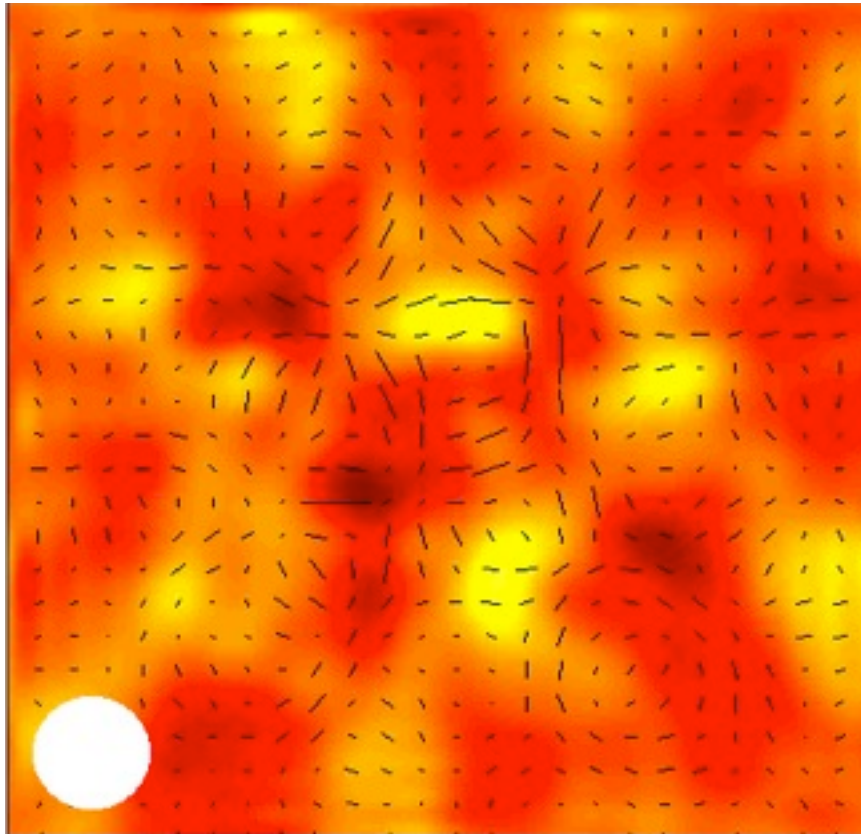


Color range 0 to 4 μ K

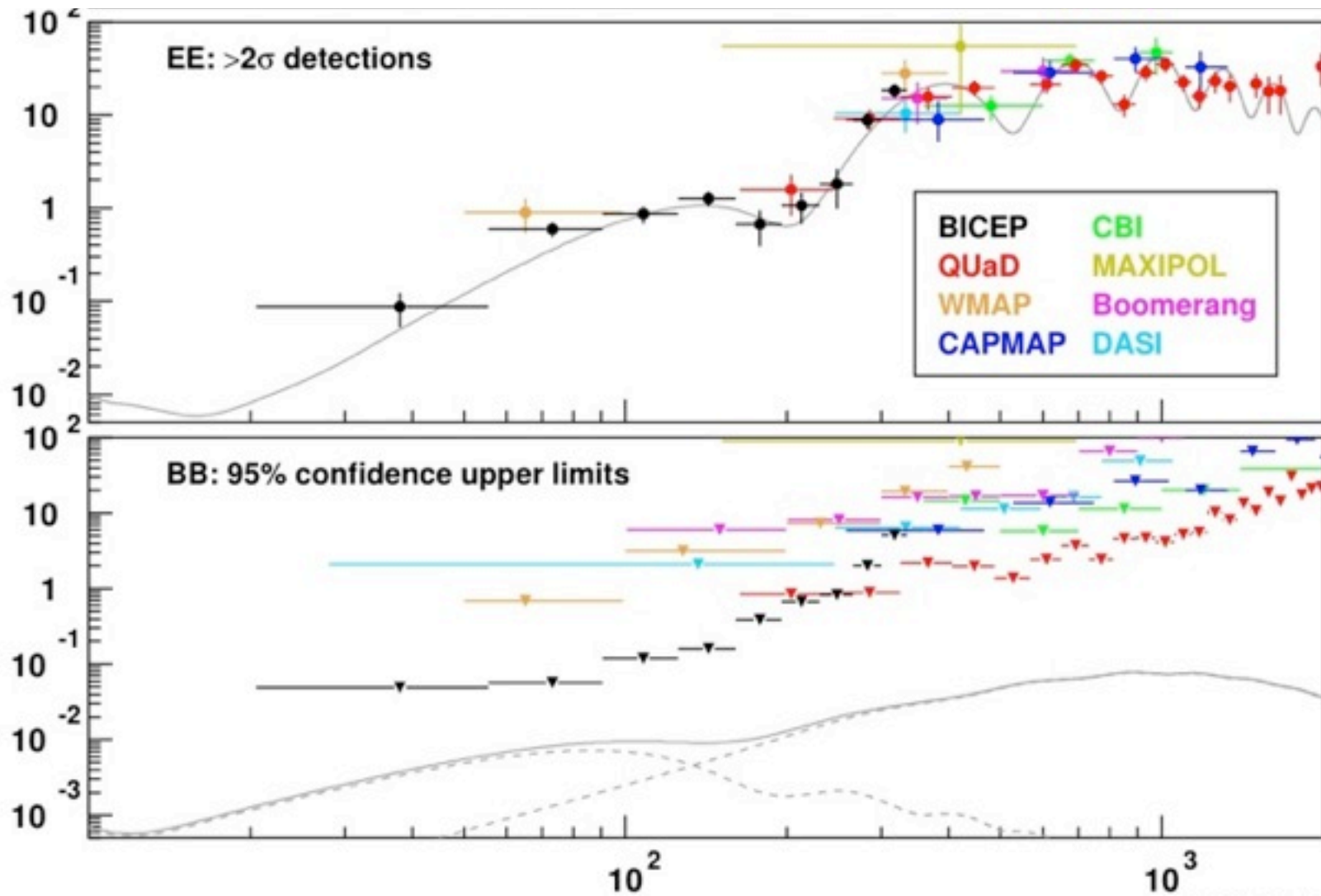
Expected polarized foregrounds
over best 3% of southern sky.
SPTpol to survey 24/7/52



Discovery of Polarization of the Cosmic Background in 2002



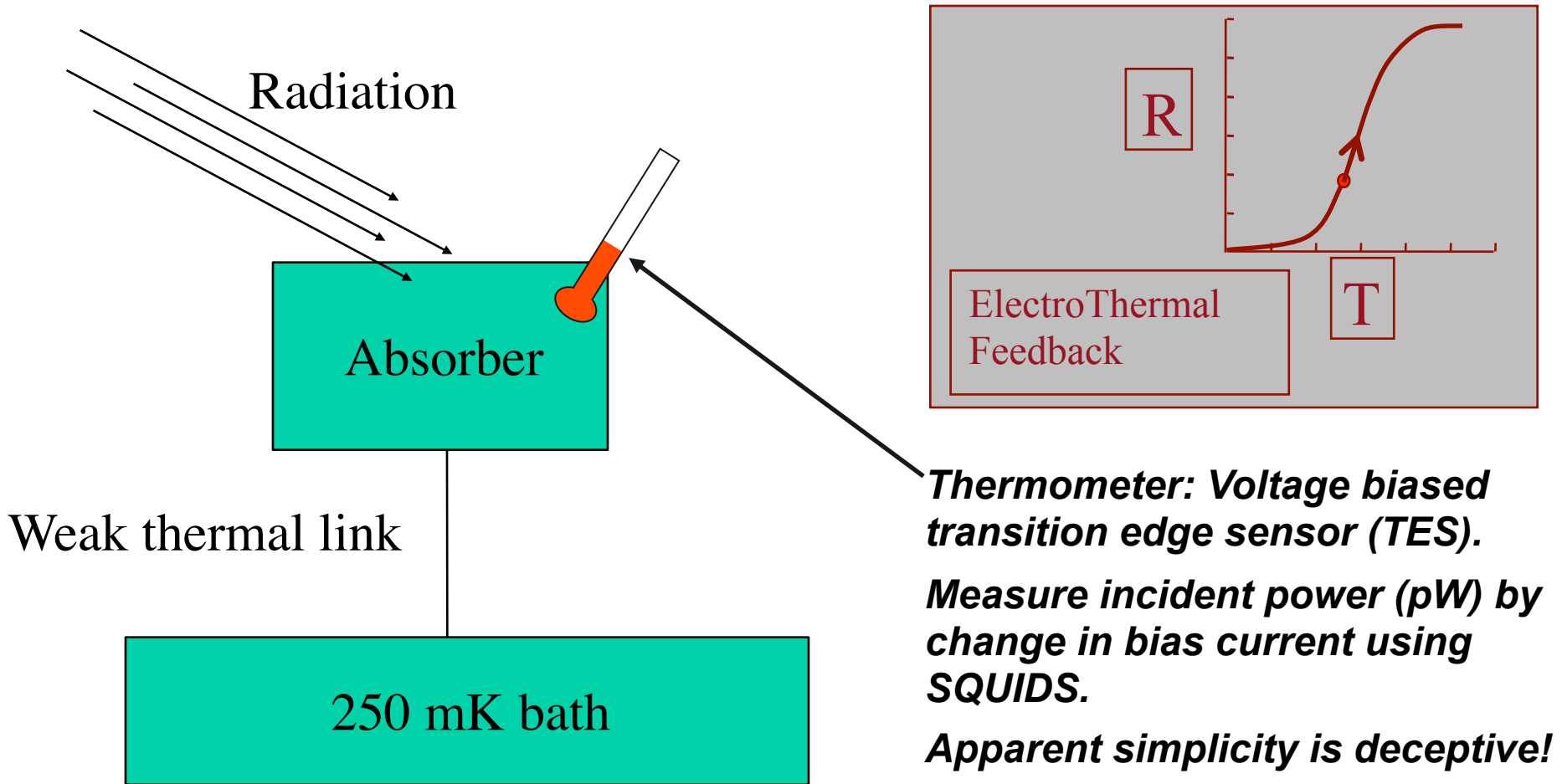
Closing in on inflation



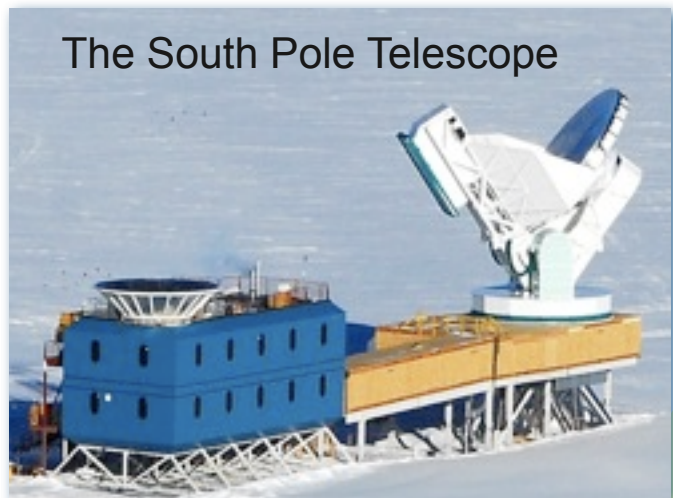
see Brown et al., arXiv:0906.1003 & Chiang et al., arXiv:0906.1181

Need more sensitivity! Need scalable, background limited, detectors.

Bolometry: A Broadly Applicable, Ultra-Sensitive Thermal Detection



Demonstrated Competencies Required for Success



Cosmic Frontier of DOE/HEP:
- ***Test inflation, probe physics at the GUT scale.***
- ***Determine masses of the neutrinos.***

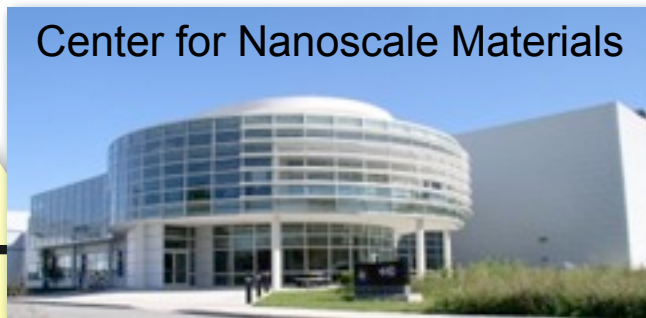
World-class Science

Materials Science

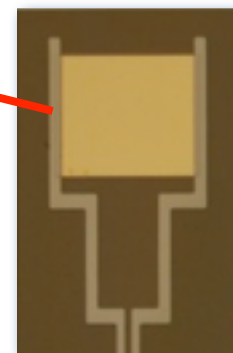
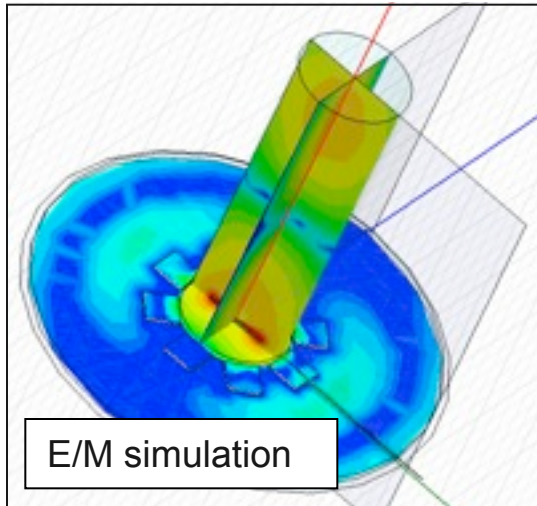
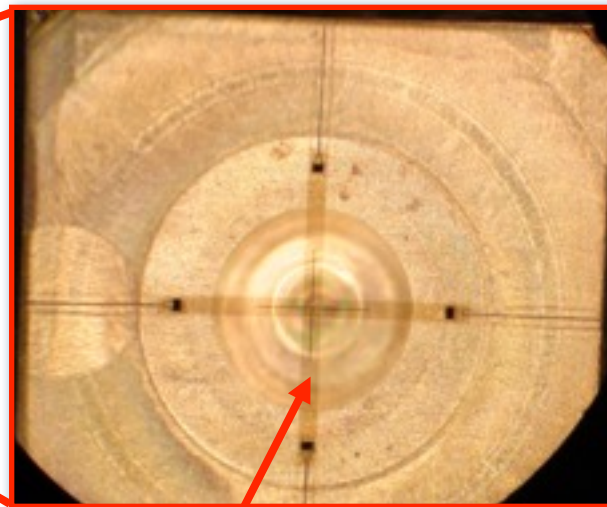
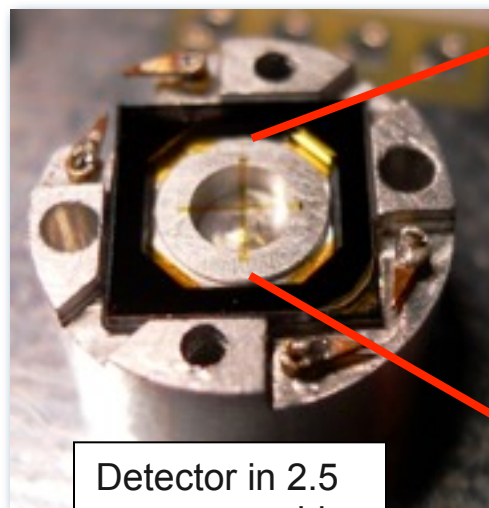
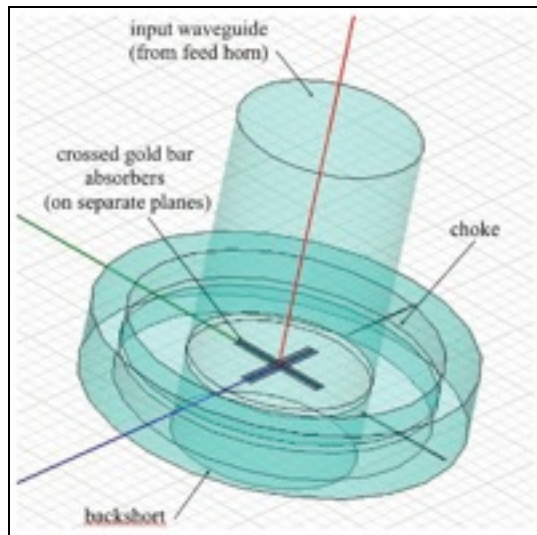
Low-Noise Superconducting Electronics

Advanced Microfabrication

Center for Nanoscale Materials

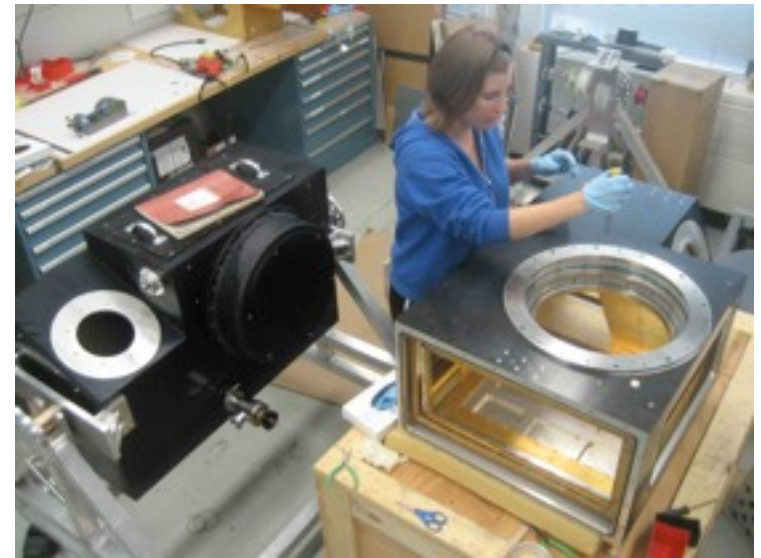
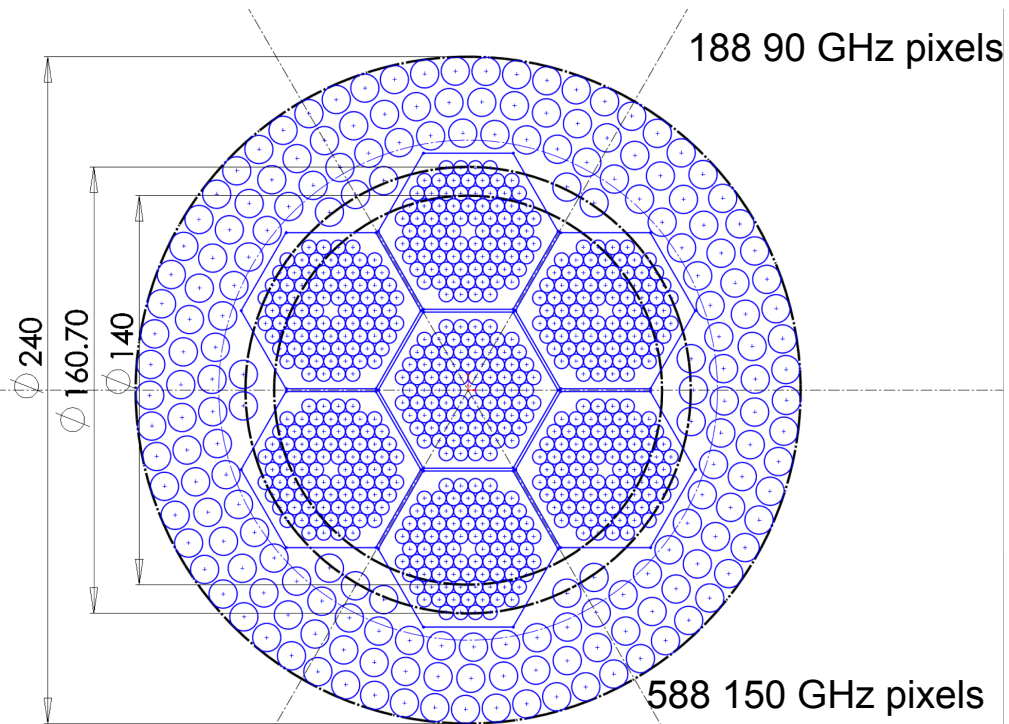


LDRD developed Argonne SPTpol TES Detector



Mo/Au proximity effect
500mK T_C bilayer TES

Focal Plane Array Layout



Argonne participation in South Pole Telescope science (SPT-SZ, DES+SPT, SPTpol).

Argonne TES polarization sensitive detector unique and critical contribution to SPTpol (LDRD funded development).

First SPTpol focal plane deployment Nov 2011.

Continued improvements through 2015.

Path for detectors for next generation CMB polarization projects and other applications.

